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DRAUGHTSMEN.

STEAM-RAISING FROM WASTE MATERIAL.

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If information relating to the design and construction of plant for utilizing the heat obtained by the burning of towns' and other refuse is wanted by the Engineer or Architect, very little, if any, will be found in the various text books to assist him. Several books have been written on refuse destruction, but the all-important points referring to detail of construction, mode of calculating size of plant, etc., are scanty, and often missing altogether.

The design of an efficient Steam-Raising Destructor Installation calls for technical and practical experience, as well as a wide knowledge of present methods of working, and of the relative efficiencies of the different types of these plants.

Combustion engineering is a speciality, and it is astonishing from my experience how few engineers really are interested in refuse. Perhaps to some of them the destructor is a sort of firebrick stove connected to a chimney! Any old thing will do for rubbish. Some users build them to their own design, the results too often being dismal failures. Then it is that they fly to the Destructor Engineer.

However, I am glad to say these instances are in the minority. Modern utilization of the heat from the combustion of towns' refuse has now established itself as an extremely important

branch of the engineering profession, calling for the steam engineer, the mechanical, structural and electrical engineer, and draughtsman.

It is my intention in this paper to briefly describe the salient points of the modern Steam-Raising Destructor, with some remarks on the chief details of construction. I do not intend to dwell on any one particular make of plant, not wishing to utilize this lecture for advertising purposes; but simply to describe the general "modus operandi" of the modern installation, with some notes on capacities, etc.

Regarding the amount of refuse each person is responsible for in this country, the figure generally taken as a basis for calculation is between 600 to 800 lbs. per annum, or, in other words, taking 300 days to the year, 1,000 persons produce on the average one ton per day, these figures being high and on the safe side for fixing size of plant. Colliery districts have the greatest quantities, owing to the very large proportion of ash due to the fact of the miners being able to get coal at a low cost. Of course, it must be understood that the figure I have given is an average approximation. The quantity of refuse will vary. In the spring, owing to the large quantities of vegetable matter, garden rubbish, leaves, etc., the weight increases.

Composition of Refuse.

Coming now to the nature or composition of domestic refuse, this is not an easy matter to imagine; it is a most heterogeneous material consisting of anything and everything, the destructor sometimes being called upon to dispose of whole harmoniums.

Large storage platforms or bunkers in the destructor house proper are to be avoided, as the air soon becomes offensive, and in the summer time the fly nuisance is a serious problem. The refuse usually collected from the towns and suburbs in the British

Isles contains by weight 40 per cent. of combustible, such as coke, ashes, coal and other inorganic matter, garbage, etc.; and 25 per cent. of material which may be considered incombustible, such as paper, tins, rags, glass, etc. The composition of street refuse, which may be termed dust in dry weather and mud in wet weather, consists essentially of the debris of stone, metal or paving, iron rust and horse dung in various stages and proportions. The moisture may be estimated at between 35 per cent. in driest and 90 per cent. in the wettest weather, ordinary mud giving off, say, 50 per cent. of water when dessicated. The dry solids may average, then, 55 per cent. to 60 per cent. of horse dung, 30 to 35 per cent. crushed stone, and 10 to 15 per cent. abraded iron.

The weight of house refuse varies from 12¼ to 15 cwt. per cubic yard. Shop refuse is lighter, sometimes as light as 7 cwt. per cubic yard. Thirteen cwt. per cubic yard is generally assumed when fixing the sizes of hoppers, etc. A "load" of refuse may be reckoned to average 20 cwts.

I am glad to say the presence of human excreta in domestic refuse is now almost a thing of the past. The sewers in most towns take care of this nowadays for suitable treatment.

Tins in the domestic refuse are turned to good account in most destructor plants. They are sorted out before the refuse is tipped into the bunkers, and are pressed and automatically baled, when they command a ready sale, chiefly for the solder which is recovered.

Fish heads, etc., are also capable of being transformed into a marketable commodity. Some towns consume more fish than others, and in consequence the refuse hoppers get a good proportion of this matter. By installing a suitable plant the fish offal can be converted into "fish manure," a valuable material for the garden. This can get a ready sale at the destructor at £8 to £10 per ton. Thirty cwts. to two tons per week can easily be

obtained from a modern destructor installation. I believe Bolton has a plant of this capacity, and it has proved itself to be a very successful financial venture.

Methods of Disposal.

Now, considering the question of disposal, it is now generally accepted that the method of burning is and has proved to be the most profitable, sanitary and final. Tipping was formerly adopted, and the Councils sold the refuse to farmers, who used it as a manure; but in the harvest time they would not take the rubbish, and it was in consequence allowed to accumulate, with the usual evil consequences. The congestion also due to bottles, tins, etc., made it not an easy matter to decide on the best way out of this difficulty.

Tipping at sea has also proved a failure, as the refuse, if taken out to sea for a long way in special barges, persists in turning up, like the bad penny, at some select watering place. The work of loading, towing and maintenance also has been found to be very costly.

A machine for pulverising the refuse has been put on the market, and one or two small plants are now working; but sorting has to be resorted to, *i.e.*, twice handling of the rubbish, and the power required to operate the apparatus is very great. The cost of maintenance is also a very serious item.

Principle of the Destructor.

A brief survey of the general arrangement of different types of destructors will be necessary before the details of construction, etc., are referred to, and it may not be out of place here to give a short description of the general working of a modern Steam-

Raising Destructor plant, though doubtless some of my audience are already familiar with this. Though the primary function of the destructor is to burn refuse, it is also often capable of performing another valuable purpose, viz., that of steam raising—in other words, taking the place of a coal-fired boiler or boilers, thus eliminating the coal bill and helping to abate the smoke nuisance. Some towns depend solely (with the exception of Sundays) on the town's refuse for providing the electricity for the trams, lighting, etc. Preston is one instance (100 K.W. per ton of refuse destroyed, being, I believe, obtained at the test).

For a steam-raising installation the destructor proper discharges its products of combustion into the flues of a Lancashire or Cornish boiler, or direct into a water tube boiler, whichever type is desired, thence direct to economiser and chimney. Here I may mention that the usual Green type of economiser in which the gases flow among the tubes is not to be recommended in destructor practice, as trouble is always experienced by the dust collecting here and very shortly restricting the areas, setting up back draught, etc. This happens in the most carefully-designed destructor, and I know of one or two cases where the economisers have had to be taken out.

If the whole of the available heat from the refuse is not required, *i.e.*, if steam is only required for driving the forced draught apparatus, a bye-pass flue must be provided, this consisting of a flue of suitable determined area which connects the combustion chamber of the destructor direct to the chimney, thus "short circuiting" the boiler. The chimney in this case would require lining with firebrick right up to the top to prevent the intense heat from cracking the shaft. As an alternative to this precaution, a cold air inlet door could be built in the base of the stack, whereby the gases could be considerably cooled down. However, lining the chimney to the top is the most satisfactory

for dealing with high temperature gases. So much, then, for the outline arrangement of the destructor.

Types of Furnaces.

I will now show by illustrations the general methods of feeding the refuse into the furnace. These may be, broadly speaking, divided into two, viz., "hand" and "mechanical charging." The first method up to now has proved itself to be generally the most satisfactory, taking all the pro's and con's into consideration. There are three types of hand-fired plants—these are the top feed, back feed and front feed, each one possessing its good points, but none differing largely in efficiency. Fig. 1 represents the top feed type. Here the refuse is raked directly from a steel hopper above the furnace into circular charging holes built in the main arch, the openings being closed by a suitable firebrick door, easily opened and closed by the fireman. An inclined roadway is necessary in most cases to bring the carts up to the level of top of furnaces, the cart then tipping direct into the hopper, which need not be in the destructor house proper, but can be in the form of a lean-to annexe. The advantages of top feed are—(1) The facility of charging, and this seems to be the only point in its favour; the bad points are the weakening of the main arch, danger of men falling into the furnace, greater capital outlay owing to the necessity for a high building and chimney to obviate the escape of gases from the charger opening. (2) When the refuse is dumped on the grate this has to be evenly spread by the fireman, which is in a way handling the refuse twice.

The front feed is the simplest and cheapest form, and is shewn at Fig. 2. To each grate there is one opening only. However, the height of grate (dead-plate) has to be suitable for both clinkering and feeding, this involving more strain on the men; and, further, the men have to face the opposite incandescent firebrick wall, which throws out a fierce radiant heat.

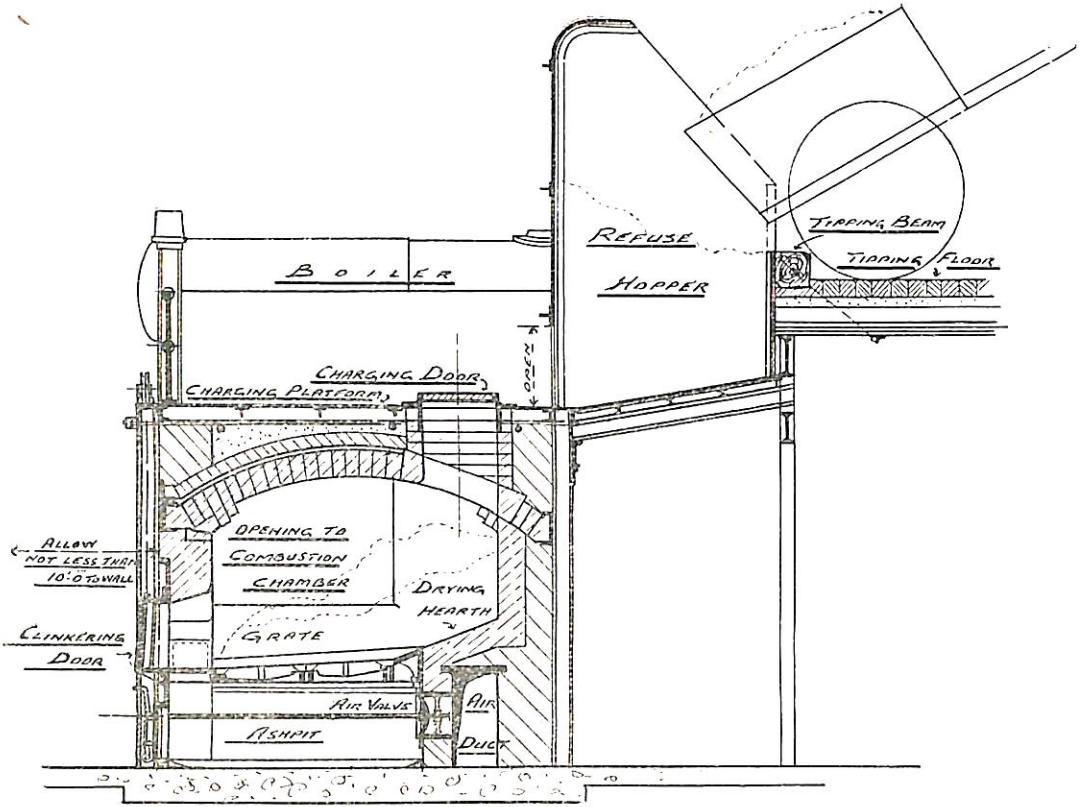

BOILER
REFUSE
HOPPER
TIPPING BEAM
TIPPING FLOOR
OPEN
CHARGING DOOR
CHARGING PLATFORM
ALLOW
NOT LESS THAN
10'-0 TO WALL
OPENING TO
COMBUSTION
CHAMBER
DRYING
HEARTH
CLINKERING
DOOR
GRATE
AIR VALVE
AIR
DUCT
ASHPIT

Fig. 1.

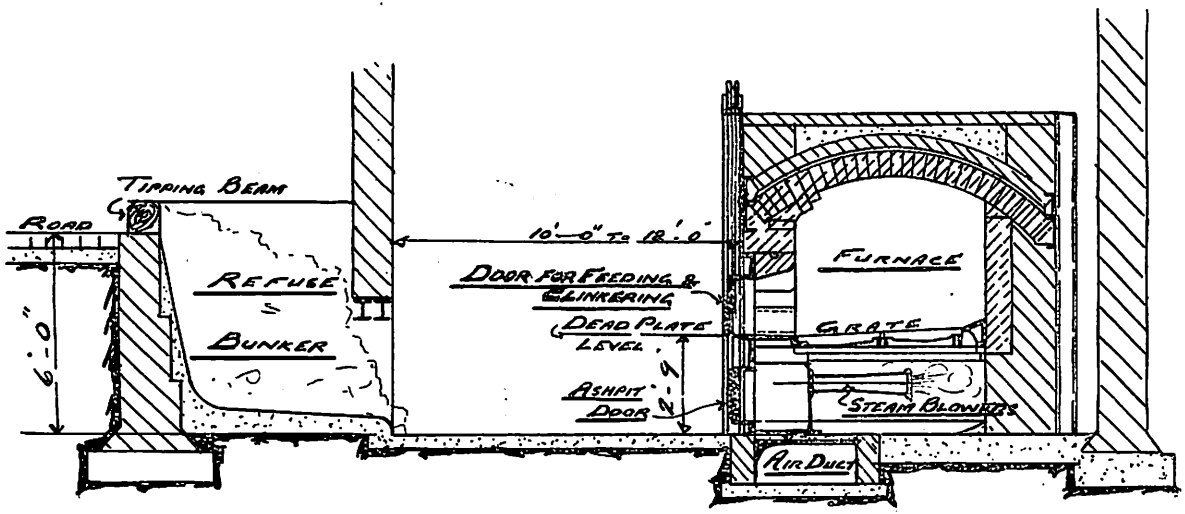

TIPPING BEAM
ROAD
REFUSE
BUNKER
6'-0"
10'-0" TO 12'-0"
DOOR FOR FEEDING & LINKERING
DEAD PLATE LEVEL
ASHPIT DOOR
2'-9"
FURNACE
GRATE
STEAM BLOWERS
AIR DUCT

Fig. 2.

The muscular effort on the part of the firemen is also very great, and the clinkering floor is not easily kept clear of hot clinker, which, when refuse is spilt on it, causes bad smells to arise.

The back feed furnace, as shewn at Fig. 3, is generally favoured. Most of the above disadvantages disappear in this type. The height from charging floor to feeding door sill can be very low (generally 18 inches), this easing the effort of the fireman. Also feeding and clinkering are absolutely separated, making it impossible to mix green refuse with hot clinker withdrawn from the fires, this causing bad smells.

Mechanical Feed and Clinkering.

When mechanical feed is adopted the refuse is in nearly all cases fed in from the top (Fig. 4 shews one system). On this plant the refuse is tipped direct from the carts into specially-designed steel skips, each holding about 12-14 cwts., and each skip being provided with hinged doors forming the bottom. These doors remain closed when the skip full of refuse is raised, and open outwards when the tension is taken off the lifting chains, this happening when the skip sits in the brackets provided, thereby delivering the refuse direct into the containers, filling up both the container legs or chutes. The charging doors are operated by means of either a hydraulic ram or suitable endless chains and gearing. The doors consist of trolleys carried on four flanged wheels which run on rails. The top of the trolley frame is covered by a steel plate which, when the door is closed (with the trolley directly over the opening to furnace), forms the bottom of each container leg. The trolley which carries a firebrick door is moved along, the refuse then discharges into the furnace, and when the chute or container leg is empty the door is moved back in position again by opening the hydraulic

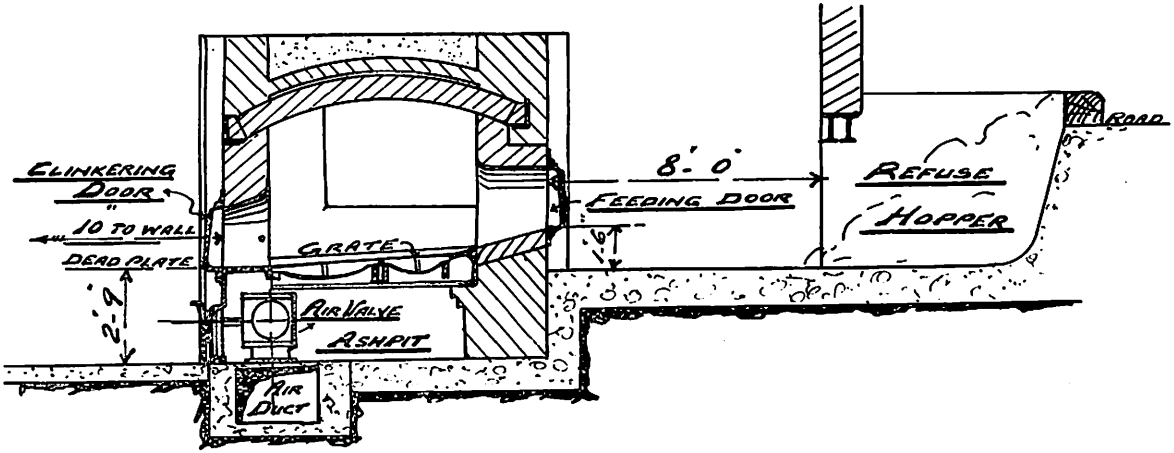

CLINKERING DOOR
10 TO WALL
DEAD PLATE
2'-9"
GRATE
AIR VALVE
ASHPIT
AIR DUCT
8'-0"
FEEDING DOOR
1'-6"
REFUSE HOPPER
ROAD

Fig. 3.

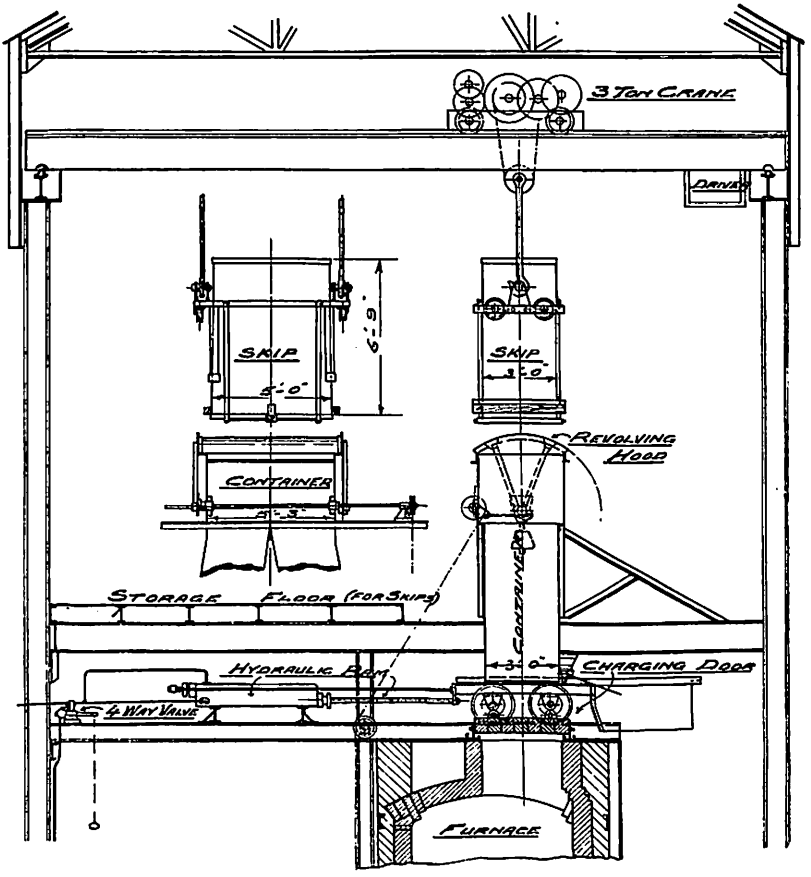

3 Ton Crane
Drive
Skip
5'-0"
6'-9"
Skip
3'-0"
Container
5'-3"
Revolving Hood
Storage Floor (for Skips)
Container
4'-3"
Hydraulic Ram
Charging Door
4 Way Valve
Furnace

Fig. 4.

valve, or putting in a clutch if gearing is adopted. For an installation on these lines a large number of skips are required if storage is necessary, and this is very costly. If the carts come in regularly three or four of the skips are placed in a pit, on the one side of which is fixed a tipping beam. When one skip gets filled it is picked up by overhead telpher and carried along straight away to the destructor, and delivered to the furnace as above described. In all top feeding mechanically operated doors a container is generally found necessary. These containers may receive the refuse direct from the carts or by hand, sometimes by means of conveyor belts; but the most practicable method, perhaps, for moderately large plants is by means of overhead skips carried by an electric overhead telpher.

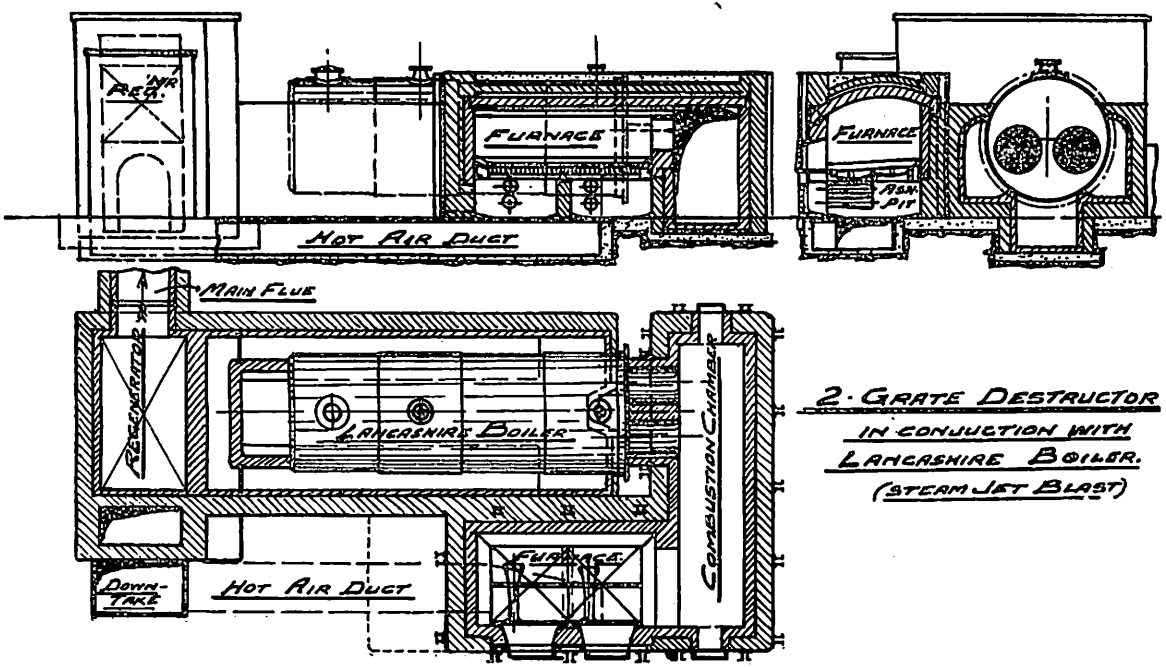
Much money has been expended of late years on automatic feeding and clinkering apparatus, but personally I am not an enthusiast in this direction. The benefits do not, taking all into consideration, justify the capital outlay. Simplicity is the thing to be aimed for by the destructor engineer. Avoid complicated mechanism where there is refuse. In my opinion hand firing for destructors takes a lot of improving on, upkeep and maintenance becoming a trifling item when the motors and toggle joints are dispensed with. These, you will understand, are my personal views on the subject of mechanical feed. There are some mechanically operated plants doing good work in this country and abroad, but I cannot help looking askance at automatic feed and clinker methods, and regarding them as "expensive luxuries."

Description of Plant.

Now, having briefly described the methods of delivering the refuse to the destructor, I shall come back again to the general arrangement of the furnaces and boiler so as to give you a

clearer idea of the working of a plant. Figs. 5, 6 and 7 shew a unit of two grates (front feed) in conjunction with a Lancashire boiler, the gases entering through the flue tubes, no grate fittings, of course, being required. The grates, as will be seen, are continuous—that is, they are not separated by division walls as some are. The ashpits, however, are separate, each having its own forced draught apparatus, steam jet or fan draught, as the case may be. This arrangement is a very good one, as it will be seen that where you have one long cell with, say, 100 square feet grate area, with four separate ashpits, when one-fourth of the cell is being clinkered or charged, the other three-fourths of the cell are always full at work. In other words, the ignited gases from the adjacent grates mutually assist the small volume of gas distilled from the newly charged section, thereby preventing any large volume of green gases from entering the combustion chamber. This is a very important point, and the "continuous" grate almost entirely prevents this. From this you will readily see the importance of feeding the refuse in small quantities on to the grates instead of dumping large charges, almost completely filling up the furnace chamber, so causing fluctuations of temperature, imperfect combustion, and a varying boiler pressure.

Referring again to our arrangement, Figs. 5, 6 and 7, it will be seen that on leaving the grates the gases enter a combustion chamber, where they become intimately mixed, a very high temperature being obtained, and pass thence into the boiler, through the firebrick lined throat tubes connecting these to the chamber. Before the gases finally enter the chimney they pass through a regenerator or air-heater, this taking the place of the usual "economiser," though really this may itself be termed an economiser.



2. GRATE DESTRUCTOR IN CONJUCTION WITH LANCASHIRE BOILER. (STEAM JET BLAST)

Figs. 5, 6, and 7,

The Regenerator.

The regenerator is a useful adjunct to the modern destructor. The gases from the boiler pass through a battery of tubes, outside which the air for combustion (supplied from a blast fan or drawn from the steam blowers in the ashpits) is passed, thereby rising in temperature and being delivered under the grates at 300 degrees to 400 degrees F., according to the temperature of the terminal gases at the boiler. Where the refuse is of a moist character, as in tropical countries, or is much exposed to rain, snow, etc., the regenerator is almost a necessity, though with good dry refuse the efficiency of the plant is not raised to a great extent by the installation of a regenerator. The gain of economy in this case will not be comparable, for instance, with the improvement made by heating the feed water in a steam boiler. The regenerator performs another useful function, viz., that of an efficient dust catcher, as the dust carried through the tubes by the gases is deposited in the large chamber underneath immediately on emerging from them, very little escaping to the chimney. With the Green type of economiser the gases pass round and among the tubes. The dust from destructor gases would be very troublesome to remove, and this would require to be frequently done.

Chimney.

The gases enter the chimney at 400 to 500 degrees F., the "pull," or draught, usually being equal to one inch of water. The height of the destructor chimney is mainly governed by local conditions. One hundred to 120 feet is a common height. The shaft should be lined a third of the way up with 4½ inch thickness of firebrick, and if bye-pass flues are installed the lining should go right up to the top, as mentioned earlier on.

The Flues.

The flues should be ample in area, and bye-flues well lined with first quality firebrick. Dampers should be avoided wherever possible. The author prefers the lifting to the butterfly type for the main flues. Bye-flue gases should not be taken through the regenerator, as the very high temperature will punish the tubes severely if always exposed to their action.

Forced Draught Apparatus.

The air required for combustion is supplied either by steam jet blowers, usually fixed in the ashpit compartments, or by fans, each having its advantage over the other. The steam jet blower is a very simple piece of apparatus, generally consisting of a bell-mouthed trumpet some three feet long, at the smaller end of which is fixed a small nozzle about four m.m. bore according to the steam pressure used, air being drawn in in large volume and at pressures varying from three-quarters to three inches water gauge. The good features of the steam blower are—(1) Simplicity and reliability; the air supply is capable of being instantly cut off whilst firing and clinkering, or adjusted by merely turning a small cock. (2) The cooling effect of the condensed steam on the firebars, which lengthens the life of these to an astonishing degree. (3) The absence of air valves, attention and upkeep of a fan and engine or motor, etc. (4) It has been stated that the steam in passing through the carbonaceous cinders forms water gas, becoming broken up and yielding two highly combustible gases, viz., hydrogen and carbonic oxide, thus greatly assisting in raising the temperature, and consuming all noxious gases evolved from the refuse.

The point against the steam blower, and apparently the only one, is its steam consumption. This is certainly higher than that

of a steam-driven fan giving the same output and pressure. The steam consumption of the blower varies from 10 per cent. to 12 per cent. of the steam generated in the boiler, whilst that of the fan is 4 per cent. to 5 per cent. Thus, when a plant is mainly required for steam raising, fans are always installed.

As regards the disadvantages of the fan, the first seems to be the dryness of the air and its effect on the firebars, as these warp and sometimes burn out if the refuse is of a high calorific value. To overcome this, however, the exhaust steam is often led into the ashpits, the floors being trough shaped to hold the water, small outside supply sometimes being led into these troughs. The other disadvantage is maintenance and upkeep of the fan, engine or motor, and attention. Where one fan is installed to serve two groups of furnaces, in the case of a breakdown the whole plant has to be shut down. This cannot happen if steam blowers are fitted.

Boilers.

Coming now to the type of boiler most suitable for the Steam-Raising Destructor, the two types that are most favoured are the Lancashire and water-tube. The former has the advantage due to its large storage capacity, allowing for a large reserve of power, and being able to be in work continuously, the steam perhaps only being required a few hours of the day, as in electricity stations. By keeping the water level high when the steam is not required much, a considerable reserve may be obtained, enabling the boiler to supply power when peak loads come, without being fed with water, until the normal working level is reached. Owing to the area of the flues being restricted for the amount of gases from the destructor, the boiler has to be larger than would be installed for the same evaporation when coal fired.

The water-tube boiler appears to be most favoured for destructor installations, its great advantage being its ability to raise steam quickly, this being very desirable in starting up the plant, especially if no outside power is available to work the forced draught apparatus. It is well adapted for resisting the sudden changes of temperature due to the heat fluctuations in the destructor, and is very suitable for high pressures. The space occupied by the water tube is less than the Lancashire for the same power, and the boiler is cleaned more easily. The front or inlet end of the setting forms a good dust catcher, and the tubes are readily cleaned by means of a steam lance inserted through doors at the side, the dust settling on the tops of the tubes, leaving the undersides clean, this being a good point. Multi-tubular fire-tube boilers are not suitable for destructor installations,—of large sizes, anyhow,—as the dust soon settles in the tubes, and is extremely difficult to remove. Even if the boiler is well constructed, preferably of the large marine type, it is not advisable to work at a higher pressure than, say, 100 lbs., leakage at the tube plates probably occurring if this is exceeded.

Dust Catchers.

Dust catchers are sometimes provided between the boiler and chimney; but generally most of the dust in a well laid out plant settles in the combustion chamber, air heater, or regenerator setting, and in the boiler setting, suitable cleaning doors being provided for its removal.

An effective type of dust catcher is in operation at Accrington, consisting of a circular chamber into which the gases are led from the main flue in such a way that they are given a swirling motion, throwing same by centrifugal force against the outside walls, and finally depositing the dust into suitable pockets. A simpler method is effected by enlarging a short portion of the

flue and building in curtain walls, so placed to give the gases a vertical zig-zag motion, depositing the dust as they pass through.

Calorific Value of Refuse.

Regarding the calorific value of domestic refuse, which influences the size of boiler or boilers to be installed, this varies, as previously stated, according to the district and the time of the year. It is generally reckoned as being one-fifth the value of coal, probably 2,000 to 3,000 B.T.U.'s per lb. It may be safely taken that good domestic refuse will give an evaporation of, say, 1 lb. per lb. of refuse, though 2 and 2½ lbs. have been obtained. With moist refuse and second-class plants ½ to ¾ lbs. per lb. can only be looked for, probably a much lower figure. As much as 3 can be obtained from sawmill refuse, shoddy waste, and similar light dry stuff. Several large shipyards are at present utilizing the heat from their refuse for steam raising.

Rate of Burning.

The rate of burning for domestic refuse per square foot of destructor grate area per hour is generally reckoned on about 50 lbs. per square foot per hour working under forced draught, and 20 to 25 under natural draught, depending, of course, on the nature of the refuse, wet or dry, etc. Given, then, the quantity of refuse to be destroyed per day or hour, and the quality, it is a simple matter to calculate the evaporative capacity or size of boiler, allowing for a margin on the calculated figures for forcing the plant, etc. Here, it must also be remembered, the area through flues, or tube spaces must also be large enough to pass all the gases, this also governing size of boiler. The forced draught apparatus should also be capable of accommodating an extra capacity of, say, 20 to 25 per cent.

Size of Fan.

As regards the amount of air required for the complete combustion of the refuse, this, of course, depends largely on the quality of the latter. Six to eight lbs. of air is commonly taken as a basis of calculations for size of fan, the resistance at fan discharge being $1\frac{1}{2}$ inches to 3 inches of water. The higher figure is taken if the air has to be forced through a regenerator.

Points for the Draughtsman.

Having now briefly outlined the main features of the Steam-Raising Destructor, a few hints to the designer of these installations will perhaps not be out of order here. (1) If possible arrange for duplicate units for plants over, say, 30 tons per day, keeping one as a reserve or stand-by. Much time, worry and money is saved in the long run by so doing. One plant one shift is good practice. (2) Keep the furnace chamber common to the number of grates—*i.e.*, have the grates continuous, with separate ashpits. Keep the number of grates large in proportion to total grate surface, and don't exceed four 25 square feet area grates per unit, as if this is exceeded the end grates next the combustion chamber get severely punished by excessive heat. (3) Avoid dampers where possible and bye-flues, and, remember, air-heaters are useful if the refuse varies much, and is open to exposure in the wet months. Don't lead bye-flue gases through regenerators; and be sure the effective area through tubes of same is not less than the area of the boiler flue tubes (if a Lancashire boiler is used; and the last section of the tube compartment if a water-tube boiler is installed). 10 to 12 per cent. above this area is a safeguard. Avoid drying hearths—*i.e.*, a firebrick sill in the destructor furnace, on which wet refuse is first placed before

being put on the grates. If the refuse is wet, go in for a regenerator. (4) Never arrange for a damper to be fixed between the furnace chamber and boiler. If the customer thinks it a fine idea to be able by this means to shut off his boiler and use it coal-fired whilst the destructor is being repaired he is making a grievous mistake in so doing. (5) Move heaven and earth not to accept mechanical clinkering and feeding. Simplicity is the watch word for the destructor designer. The simplest way to remove the clinker is after all by hand, raked into buckets carried on an overhead mono-rail running the whole length of the cells, thence out through the building to be quenched or otherwise. (6) Make all the flues of large area, and avoid right angle bends. Allow for possible extension of plant in fixing size of same, also chimney. (7) It is important that the "draughtsman," before getting out his scheme, visits the site himself, taking note of all existing buildings near the proposed position, inspecting the refuse, and getting as much out of the engineers present as possible, to enable him to put forward a profitable and efficient plant.

Steady Steam Pressure.

The maintenance of a steady steam pressure is very important, especially in large installations in connection with electricity stations. This can be done if the plant is well designed, and the clinkering and charging is kept in rotation. The clinkering should not be done too often: every hour and a half, according to the quality of the refuse, this ensures a good hard clinker, and cures the evil of fluctuating boiler pressures.

The efficiency of the plant depends to a large extent on the way it is handled. Better evaporative efficiencies are often obtained over short periods by increasing the amount of labour employed, feeding in small quantities, and generally working the

plant at its full capacity. Large sudden charges of refuse, say, 10 to 12 cwts, at a time dropped on the grate, cause a rapid fall in temperature and corresponding fluctuations in pressure. This has a very bad effect on the fire-brick lining, causing fracture, due to the sudden contraction and expansion. Moderately thin fires and careful stoking all go to make the destructor an efficient steam-raiser.

Clinker Disposal.

Coming now to the disposal and use of the clinker, this forms an important part of the installation, and in large plants the quantity of clinker which amasses is very considerable. By installing a crushing and screening plant the clinker can be turned to good account. Good mortar can be made from it, also paving flags and bricks.

The question of cooling the clinker has been a vexed one. Where the site is small it is inconvenient and dangerous to have large heaps of red hot clinker about the ground. There is no doubt the best means to cool the clinker is to immerse it bodily as it comes away in the skip from the furnace; but this requires special plant, *i.e.*, a quick lowering device and a special tank, with means of easily and quickly cleaning out, and renewing with cool water. In some plants this tank is in the form of a lift, and is elevated when the clinker is cool and the water run off, and then discharged direct into a crusher, whence it is then elevated and directed into the revolving screens. Another way to cool the clinker is by spraying, the bucket entering with its load into a closed compartment fitted with the necessary water jets. Removing the clinker "en masse" from the furnace, as is sometimes done, is in my opinion not good practice. It is certainly expeditious, but two reasons present themselves, viz., the clinker is often "green" or unburst in the middle of the cake,

rendering it more or less useless as an aggregate for mortar or concrete; and, secondly, the quick removal of the whole contents of the furnace causes contraction and cooling of the firebrick lining. Hand-clinkering, then, in my opinion, is the best method; trying for the men, doubtless, but this does not appear to be avoidable.

Clinker Plants.

The percentage by weight of clinker obtained from the refuse depends again on the nature of the material burnt. It may be anything from 16 per cent. to 35 per cent., or even higher; for municipal destructors 28 to 30 is generally obtained, and reckoned on as base for fixing the size of clinker plant, if one is installed. For instance, a three-grate unit destroying $1\frac{1}{2}$ to $2\frac{1}{2}$ tons of refuse per hour, providing no future extension to the plant is likely, the clinker plant capacity would be rated at one ton per hour, this being quite on the safe side. As before mentioned, the clinker plant consists of a pair of crushing rolls, elevator and revolving screen. These plants do not take much power, a two ton per hour plant requiring some 18 to 20 H.P. They are generally driven by a steam engine, but of course may be motor driven. The presence of iron in the clinker has led to the adoption of magnetic separators after the crushers have dealt with it, but this method has not met with any very marked success. Slab making plants are often put down at the destructor site, making the installation very complete.

Money Value of Refuse.

The value of refuse for generating electricity must be considered from the point of view of the number of kilowatts generated per ton of refuse burnt, and cannot be based on snap tests. Some engineers refuse to be convinced by the destructor specialist

what his particular make will do, by his displaying a number of elaborate and wonderful test diagrams. I for one have a certain amount of sympathy with those engineers. There is generally a marked difference on the figure of, say, a year's working, and a test or series of tests. For having a good idea of the capability of the plant under their direction the units taken over a year's working should be considered.

From results of calculations made from a number of destructors in conjunction with Electricity Stations, the average number of kilowatts generated per ton of refuse burnt appears to range from 20 to 40. Much higher output has been obtained over short periods, this figure reaching 100, and in one or two cases even higher. Fig. 8 shews a diagram representing the kilowatts generated during a twenty-four hour test. The destructor was

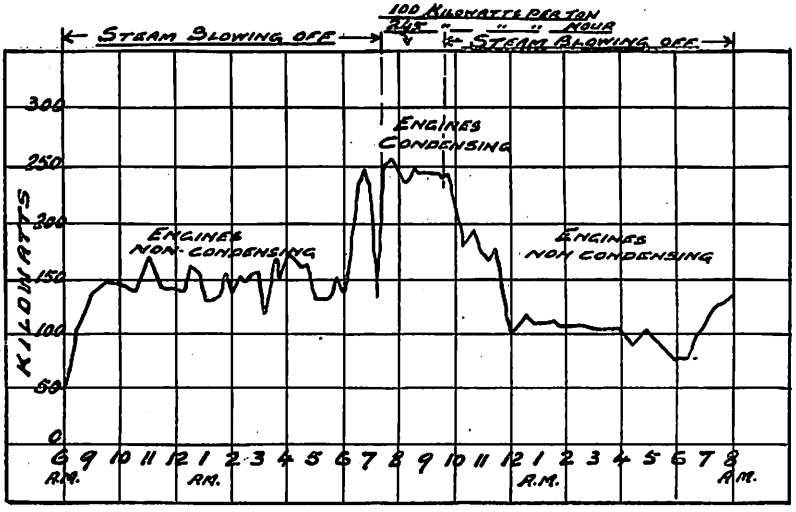


Fig. 8.

of the continuous grate type the total grate area being 75 sq. ft.. the boiler being a Babcock and Wilcox of some 1827 sq. ft.

heating surface, with superheater. The total refuse burnt in 24¼ hours was 63¼ tons, *i.e.*, the average rate of 2·6 tons per hour. The electrical output at full load was just approaching 100 kilowatts per ton of refuse, the output for the hour being 245 kilowatts.

Cost of Burning.

As regards the cost for dealing with refuse in the destructor this may be anything between 8d. and 1/9d. per ton, including wages of stokers, foremen, and other hands employed on the plant, and excluding other items such as repairs, removal of clinker, water, light, rates, etc. These will add 5d. to 8d. per ton on the above charges. The total expenditure, therefore, including all the above charges may vary between 1/7 and 4/2 per ton of refuse dealt with. A plant at King's Norton has given very good results, and for a period of about six months the labour cost was about 7d. per ton of refuse, the rate of wages being 4/8 per man per shift of eight hours. The cost of cleaning and supervising the plant and cleaning machinery, building, including waste, oil, etc., was 1¾d. per ton. The plant referred to consisted of three units each containing three grates, water tube boiler, regenerator and fan draught, etc.

The Utilization of the Gases from Destructors.

This we have seen is of great value. Most large towns nowadays have a destructor, and a good many plants used are in connection with the electricity works, in spite of the power required by them only being for a short period of the day. Manufacturers are now keener than ever on utilizing their refuse, even if of a very poor nature, such as tannery waste, for obtaining power, the war largely accounting for this. With coal at the

tremendously high price it is at present, there is a run on the Steam Raising Refuse Destructor. People have learnt to be thrifty, and do not waste anything that can be made use of; and, after all, this is approaching the ideal state, is it not?

The largest destructor plants that I know of are in Hamburg and Rotterdam, the latter mechanical fed, and dealing with some 300 tons of refuse per day, whilst the former plant is a top feed hand-fed, and it is, I believe, of the same capacity.

In conclusion, I hope my brief description of modern plants for disposal of waste material will further interest all who are considering the question of utilizing of heat from materials other than coal. Many thousands of horse-power in this country are obtained from what was, not so many years ago, considered to be useless rubbish. Who can prophesy what use will be made in a short time hence of similar waste, filth and materials? The extraction and purification of valuable grease from sewage sludge, abbattoir offal, etc., is now making great strides, successful plants being now in operation for this. As mentioned at the outset, I have refrained from booming up any particular make of plant. In fact I have not mentioned any names, as so many papers nowadays seem to me to assume the nature of trade catalogues and advertising mediums, by singing the praises of one particular firm's goods.

Official Particulars of Test on Destructor Plant.

Date of test	
Duration of test	8 hours.
No. of cells (*i.e.*, grates)	2.
Grate area of each cell	25 sq. ft.
Total grate area	50 sq. ft.
No. and type of boiler	1 Lancashire, 2 flues, 28ft. 0in. x 7ft. 6in. dia.
Total refuse burnt	14 tons, 11 cwt., 2 qrs. = 32648 lbs.
Total water evaporated	50625 lbs.
Average rate of burning per hour	4084 lbs.
Average rate of burning per hour per sq. ft. grate area	81·6 lbs.
Average rate of evaporation per hour	6325·5 lbs.
Water evaporated per lb. refuse with feed water at 42·5° F.	1·55 lbs.
Equivalent evaporation per lb. refuse from and at 212° F....	1·89 lbs.
Average temperature of combustion chamber ...	2172° F.
Average temperature of chimney base	700 F.
Average temperature of air-blast after heater ...	336 F.
Average temperature of feed water	42·5° F.
Average steam pressure	147 lbs. per sq. in.
Total quantity of clinker	$3\frac{1}{4}$ tons = 7280 lbs.
Percentage of clinker to refuse burnt	22 per cent.

Average analysis of products of combustion—

CO_2	O	CO	N by diff.
15·6	4·8	00	79·6

Maximum temperature combustion chamber ...	2417° F.
Minimum temperature combustion chamber ...	1787° F.
Capacity of plant (2 grates) per day of 24 hours...	43 tons, 14 cwts., 2 qrs.
Labour cost per ton	7d.
Rate of wages paid for furnace men	30s. per week of $56\frac{1}{2}$ hours.